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Gertsch

INSTRUCTION BOOK
for
MODEL FM-5
FREQUENCY DIVIDER

QC CAL/CERT
PROCEDURES
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ELECTRONIC INSTRUMENTS

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INSTRUCTION BOOK

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FREQUENCY DIVIDER

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GERTSCH PRODUCTS, Inc.

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SECTION I - GENERAL DESCRIPTION

1. PURPOSE OF THE INSTRUMENT

The Gertsch Model FM-5 Frequency Divider was designed as an auxiliary piece of equipment to extend the range of the Gertsch Model FM-3 Frequency Meter or Gertsch Model AM-1 Frequency Interpolator down to 200 kc. With the FM-3 or AM-1 as a driver, the Model FM-5 Frequency Divider is capable of generating any frequency in the range 200 kc. to 20 mc. The FM-5 also has a detector system which allows unknown frequencies in this range to be measured. Frequencies below 200 kc. may be measured if they are strong enough to produce detectable harmonics above 200 kc.

2. ACCURACY

The FM-5 contributes no frequency error. Frequencies may be generated or measurements made with the accuracy of the driving unit. This would be .001% when used with the Gertsch Model FM-3 Frequency Meter and 1 part in 10^7 when used with the Gertsch Model AM-1 Interpolator.

3. PERFORMANCE DATA

Available Output:

Low Band	200 kc. - 2 mc.	Unloaded:	50 millivolts
		50 Ohm Load:	5 millivolts
High Band	2 mc. - 20 mc.	Unloaded:	50 millivolts
		50 Ohm Load:	5 millivolts

Sensitivity (Input required to zero beat within .0005%):

Low Band	200 kc. - 2 mc.	30 millivolts
	50 kc. - 200 kc. (Sine Wave)	2 volts
High Band	2 mc. - 20 mc.	5 millivolts

Sufficient output is available to make direct Lissajou pattern comparisons with a moderately sensitive oscilloscope.

4. VARIOUS TYPE OF MODEL FM-5

The Model FM-5 is available in three forms as follows:

A. The Model FM-5. This includes the basic unit mounted in a portable

carrying case with provisions in the lower part of the case for one set of dry cell batteries. A switch and plug are provided so that external power may be fed to the instrument to conserve batteries when AC power is available. The Model PS-3C is available for this purpose. It consists of a small portable power supply in a separate carrying case fitted with a plug to match the one on the FM-5. The Model PS-3C may also be used with the FM-3 Frequency Meter, but will not supply sufficient power to operate both an FM-3 and an FM-5. It is designed for use with 115 or 230 volt, 50 - 60 cycle, AC power.

B. The Model FM-5/PS-3. This model consists of the basic FM-5 unit mounted in the same portable carrying case as the Model FM-5 but with a PS-3 Power Supply mounted in the lower compartment, thus providing a portable instrument which will operate from 105 - 125 volts, 50 or 60 cycles. The transformer used in the PS-3 has a dual primary which may be reconnected for 230 volt, 50 - 60 cycle operation. A three wire power cord is supplied so that the case of the instrument may be grounded through the cord if desired.

C. The FM-5R is a rack-mounted version of the instrument, complete with power supply with a standard 19" x 8 3/4" rack panel. This model is also available with a metal carrying case at extra cost.

5. FUNCTION OF EQUIPMENT

The Model FM-5 is designed to divide a signal in the 20 - 40 mc. range by exactly 10 or exactly 100 and to provide an output which is rich in harmonics. By this means any frequency in the range 200 kc - 20 mc. may be generated. If the output is matched to an unknown signal by the zero beat technique, any unknown frequency in this range may be measured.

6. EQUIPMENT SUPPLIED

As shipped, the various models of the FM-5 are supplied with the following equipment. Additional equipment required for complete operation is indicated. For accurate frequency measurement a 20 - 40 mc. driving source such as the Gertsch FM-3 or Gertsch AM-1 is required for all models.

A. Model FM-5.

1. The Model FM-5 is mounted in a carrying case with an instruction book.

2. Additional Equipment Required:

a. One set of batteries consisting of three Burgess M30 or equivalent 45 volt "B" batteries, and three Burgess 2F4 or equivalent 6 volt "A" batteries. For details of battery installation see Figure IV-2 and refer

to Maintenance Section IV-4.

b. One set of headphones. The FM-5 was designed for used with 600 ohm magnetic phones. Impedance is not critical.

B. FM-5/PS-3

1. This unit consists of the FM-5 mounted in a carrying case with a type PS-3 Power Supply mounted in the lower portion. It is supplied with power cord and instruction book.

2. Additional Equipment Required:

a. One set of headphones, same as FM-5.

C. FM-5R

1. This consists of the basic FM-5 unit and a Model PS-3 Power Supply mounted on an 8 3/4" x 19" rack panel, supplied with power cord and instruction book.

2. Additional Equipment Required:

a. One set of headphones, same as FM-5.

7. POWER CONSUMPTION

A. Model FM-5 (battery operated). When used with the recommended batteries, the Model FM-5 has a battery life of approximately 8 hours intermittent duty. Battery life may be extended by shortening the periods of operation. It is not necessary to allow this instrument to warm up beyond the time required for the tubes to reach normal emission.

When used with an external power supply other than the Gertsch Model PS-3 the following current and voltages are required.

1. Plate supply 135 volts, 22 - 40 ma. regulated. See Figure I-1 for suggested regulator circuit.

2. Filament supply 6.3 volts at 1.28 amperes. Regulation is not normally required.

B. Model FM-5/PS-3 and Model FM-5R. These units require a power source of 105 - 125 volts, 50 - 60 cycles. Power transformer primaries may be reconnected for 210 - 250 volts (See Figure IV-3). Total volt ampere consumption is 37 VA.

8. DIMENSIONS AND WEIGHTS

A. Model FM-5. Width 11", Depth 9 1/2", Height 14", Weight 30 lbs. including batteries, 17 lbs. less batteries.

B. Model FM-5/PS-3. Dimensions same as FM-5. Weight 19 1/2 lbs.

C. Model FM-5R. Width 19", Height 8 3/4", Depth (overall) 9 1/8", Weight 19 1/2 lbs.

SECTION II - OPERATION AND ADJUSTMENT

1. GENERAL

The FM-5 dial is calibrated roughly in frequency from 20 - 40 megacycles. When readings are taken or when the instruments are adjusted to generate a prescribed frequency, this dial should agree with the high frequency oscillator dial on the Model FM-3 or Model AM-1 which is used as a driver. Accurate frequency readings are taken from the driver and any necessary corrections for dial calibration and crystal temperature are applied. The FM-5 output frequency is this frequency times .1 or .01 depending upon position of the range switch. The result is the fundamental frequency of the FM-5. When harmonics of this frequency are used this frequency should be multiplied by the integer representing the harmonic used. Conversely, when the instrument is used to measure a harmonic of an unknown frequency, the FM-5 frequency should be divided by an integer representing the harmonic used. See Section II-G for the method of identifying the harmonic order when measuring an entirely unknown signal.

2. METHOD OF OPERATION.

In the following instructions the word driver will be used to refer to the source of 20 - 40 mc. signals fed to the FM-5. This would ordinarily be a Gertsch Model FM-3 or Gertsch Model AM-1.

A. To Measure a Frequency.

1. Place the power switch of the driver unit in the ON position and allow the normal warm up time. Turn the FM-5 function switch from OFF to BEAT position. Set the range switch in the X.1 position if the unknown signal is known to be above 2 megacycles. If the unknown signal is known to be below 2 megacycles, set the range switch in the X.01 position. If the unknown source is entirely unknown, start with the range switch in the X.01 position. See Section II-G for the method of measuring entirely unknown signals.

2. Plug the phones in the phone jack and provide suitable coupling to the source being measured.

3. With the FM-5 function switch in the BEAT position, locate the frequency to be measured by turning the FM-5 tuning knob in the vicinity of the expected frequency as indicated on the dial until a beat note is heard. Tune to zero beat. It is not necessary to precisely zero beat at this point.

4. Place the FM-5 function switch in the LOCK position and connect the driver output to the FM-5 20 - 40 mc. input jack.

5. With the driver function switch in the BEAT position, tune the high frequency oscillator toward the frequency read on the FM-5 dial.

When this frequency is approached, the output meter on the FM-5 should swing up to about half scale. As tuning continues a beat note will be heard. Adjust to zero beat.

6. Turn the function switch of the driver to the READ position and set the megacycle selector knob to the integral number of megacycles indicated on the HFO dial. Transfer the headphones to the driver and tune the LFO until lock in is reached. Center the LFO dial between the two lock in squawks. With practice the lock-in condition can be recognized with the phones in the FM-5, and it will be unnecessary to transfer the headphones. When this is done, check to be sure the HFO is properly locked as described in step number 7.

7. With the phones in the FM-5 tune the driver LFO until zero beat is reached. To be sure the instruments are properly locked, rock first the driver HFO dial and then the FM-5 tuning dial. Small detunings of either dial should not change conditions as heard in the phones.

8. If the driver is an FM-3, transfer the headphones to the driver and follow the normal calibration procedure at the nearest check point. Then turn the LFO dial back to the setting found in step 7.

9. With the headphones in the FM-5 repeat step 7. Zero beat precisely against the unknown.

10. Read the driver frequency and apply the corrections indicated on calibration curves in the case of an FM-3. With an AM-1 no correction should be necessary.

11. Move the decimal point in the corrected driver frequency one or two places to the left corresponding to the X.1 or X.01 position of the range switch on the FM-5.

12. Multiply by the order of the harmonic being used. The result is the frequency of the source being measured. Suggested harmonics for various frequency ranges are as follows:

Range: X.01		Range: X.1	
Frequency	Harmonic	Frequency	Harmonic
200-400 kc.	1	2.0-4.0 mc.	1
400-800 kc.	2	4.0-8.0 mc.	2
800-1600 kc.	4	8.0-16.0 mc.	4
1600-2000 kc.	5	16.0-20.0 mc.	5

B. TO GENERATE A FREQUENCY

1. Turn on power to driver and FM-5. Warm up procedure given in step 1, Section A, should be followed. In the case of a battery operated FM-5, battery drain may be minimized by leaving the FM-5 function switch in the BEAT position until the driver has been adjusted.

2. Divide the desired frequency by the appropriate harmonic factor to obtain an instrument frequency in the range 200 - 400 kc, or 2-4 mc. For example, to generate 8.4 mc., an appropriate factor is 4, therefore, the instrument frequency would be 8.4 divided by 4 or 2.1 mc.

3. Move the decimal point in the FM-5 instrument frequency 1 or 2 places to the right to obtain a frequency in the range 20 - 40 mc. Set the FM-5 range switch to the appropriate position.

4. Adjust the driver to generate the frequency found in step 3. Follow the normal generating procedure for the driver. Connect headphones to the driver unit in order to locate the lock-in condition of the driver HFO.

5. Connect the driver output to the FM-5 20 - 40 mc. input jack.

6. Turn the FM-5 function switch to the LOCK position. Tune the FM-5 in the vicinity of the frequency indicated on the driver HFO dial until a maximum is reached on the FM-5 output meter.

7. The desired output frequency is now available at the FM-5 200 kc. - 20 mc. input output connectors. If modulated output is desired, place the function switch in the MOD position. Output amplitude may be varied by adjusting the RF level control.

C. METHODS OF COUPLING

The method of coupling should be varied according to the type of source being measured and the relative output. Sufficient coupling to a transmitter or oscillator of reasonable power may be obtained by plugging the antenna into the BNC input, output jack of the FM-5 and coupling to the near radiation field of the transmitter. A length of insulated wire connected to the hot input-output binding post may be used as an antenna for greater coupling or for direct capacitive coupling to a weaker source. An insulated lead wrapped around the antenna may also be used for this purpose. A link consisting of a few turns of wire connected by twisted pair to the input-output binding posts may be used for coupling to inductors. Avoid coupling excessive amounts of power into the instrument. Power greater than a few milliwatts may make it difficult to avoid overloading the detector and power levels much greater than one watt may cause damage to the R.F. level control potentiometer or frequency multiplier diode in the FM-5. Direct connections to coaxial line may be used when measuring low power signal generators. Any of the coupling means mentioned above may be used to transfer energy generated in the FM-5 to a receiver for calibration of the receiver or when using the receiver as a beat note detector to measure the frequency of a weak unknown signal.

D. USE OF AN AUXILIARY RECEIVER TO MEASURE WEAK SIGNALS

To measure the frequency of weak signals, such as the signals of a distant transmitter, the following procedure is recommended:

1. Locate the frequency to be measured on a receiver with adequate sensitivity.

2. Provide suitable coupling between the receiver antenna terminal and the FM-5 Frequency Divider.

3. With the FM-5 function switch in the BEAT position and the range switch set to . 1 if the frequency is indicated on the receiver is over two megacycles or . 01 if the frequency is below two megacycles, tune the FM-5 until a beat note is heard in the receiver.

4. Change the receiver tuning slightly and note whether or not the beat note frequency changes. If the beat note frequency changes the response is an image response, or a response with a local oscillator harmonic, or other type of spurious receiver response. If this is the case continue tuning the FM-5 until a proper response is obtained, that is, one in which the beat note frequency does not vary for slight receiver tuning changes.

5. Follow the normal procedure for measuring a frequency except that headphones should be connected to the receiver instead of the FM-5.

6. When finding the exact zero beat, use of the modulation feature of the FM-5 may be helpful. This will produce a tone in the receiver output which is modulated at the frequency of the difference between the FM-5 output and the unknown. Use the FM-5 without modulation first to avoid beating the unknown against a side band modulation product. If the receiver has an "S" meter, it may be used as a visual beat indicator.

E. LISSAJOU PATTERN METHOD OF MATCHING FREQUENCIES

The FM-5 output must be very closely matched to an unknown frequency if the accuracy obtainable with the FM-3 - FM-5 or AM-1 - FM-5 system is to be used. With the AM-1 - FM-5 combination, frequencies may be measured to .00001%, which is . 02 cycles at 200 kc. It is difficult to match frequencies this closely by the audio beat-note method.

If the signals can be displayed as a lissajou pattern on an oscilloscope, a visual indication is obtained by which the frequencies can be precisely matched.

To do this, connect the FM-5 output to deflect the oscilloscope along one axis, and connect the unknown to cause deflection on the other axis. If the oscilloscope amplifiers are not identical in gain and frequency response, connect the signals according to level and frequency to obtain the clearest pattern.

The FM-5 and driver may now be adjusted to stop the motion of the pattern.

Since the FM-5 output is a peaked wave which is rich in harmonics, the pattern will not look much like the Lissajou patterns obtained with sine waves.

Difficulty may be encountered in determining the frequency ratio of the two inputs by the method of counting peaks of the pattern. Some of the peaks may bunch together so closely that they cannot be counted.

If the unknown is roughly determined first by the normal audio zero beat method, there will be no need to interpret the Lissajou pattern. A stationary pattern indicates the exact zero beat point.

Two other methods of using an oscilloscope to match frequencies follow:

1. Synchronize the sweep from one signal and display the other on the vertical axis. Adjust for a stationary pattern.

2. Display one signal on the scope, either in the normal manner or as a Lissajou figure with the same frequency on both axes. Connect the other signal to the "Z axis" or "blanking" terminal to intensity modulate the pattern. Adjust for a stationary pattern of bright spots.

F. SPURIOUS RESPONSES

When the FM-5 is locked to the output of a Gertsch Model FM-3 Frequency Meter or Model AM-1 VHF Interpolator, spurious responses occurring in the driver may sometimes be heard in the audio output of the FM-5. Refer to the instruction book for the driver for the method of identifying spurious responses. If the driver is connected to the 20 - 40 megacycle input jack of the FM-5 while searching for an unknown signal with the FM-5 in the BEAT position a beat note may be heard when the FM-5 is tuned past the driver frequency. This may cause some confusion although it is not possible to get an erroneous measurement from this source since this beat note cannot be found when the FM-5 is in the LOCK position. To avoid this response disconnect the driver or tune it away from the frequency range being searched.

G. METHOD OF MEASURING THE FREQUENCY OF AN ENTIRELY UNKNOWN SOURCE.

It is possible to measure the frequency of an entirely unknown source with a heterodyne type frequency measuring instrument such as the FM-5. This is done by taking two measurements, matching two adjacent harmonics of the FM-5 to the unknown signal in the case of an unknown which is above the fundamental range of the FM-5, or by measuring two adjacent harmonics of the unknown where the unknown is below the range of the FM-5. The fundamental range of the FM-5 will be 2-4 mc., or 200 - 400 kc., depending upon position of the range switch. There is a range of frequencies for which only one proper response will be obtained. This case is difficult to resolve if the signal is entirely unknown, since the response may be against the second harmonic of the unknown, or the unknown may be in the fundamental range of the FM-5, or the second harmonic of the FM-5 may be beating against the unknown. This difficulty may be resolved by turning the range switch and making measurements on the other range. This will put the FM-5 definitely above or below the unknown frequency. In using this procedure it must be remembered that we are interested only in responses where the fundamental of one of the signals is involved. Either harmonics of the FM-5 beat against the fundamental of the unknown, or the fundamental of the FM 5 beats against harmonics of the unknown. These will be called proper responses. In between these responses other beat notes will be heard as a result of harmonics of both sources beating together. These signals are normally considerably weaker than the proper ones and can be distinguished by their relatively low level. To do this the RF level control of the FM-5 should be adjusted to avoid stauration of the detector system on the proper responses. Turn down the RF level control until a noticeable decrease in volume results. If the unknown signal has harmonics which are nearly as strong as the fundamental, identification of the proper responses may be more difficult. If the proper responses cannot be distinguished by level, they may be identified by checking the rate at which the pitch of the audio beat note varies as the FM-5 frequency is varied. If the FM-5 frequency is shifted 1 kc, the beat note will change by 1 kc. if the response is against the FM-5 fundamental, 2 kc. if the response is against the second harmonic, and so forth.

The "widest" responses will always be the proper ones, and they will be about twice as wide as the widest improper response.

The procedure for finding unknown frequencies together with derivation of the formulas used follows:

1. Frequencies known to be above the fundamental range generated by the instrument.

a. Use the normal measuring procedure with the

function switch in the BEAT position start at the low frequency end of the dial and tune to the entire range picking out the strongest beat notes. Turn down the RF level control until a noticeable reduction in volume occurs on the strongest beat notes. This will avoid saturation of the detector system so that relative level of the signals may be more easily distinguished. Ignore the relatively weak signals between the strong beat notes. Note the approximate frequencies of the strong signals and go back to the first strong beat note against the unknown signal. Measure this frequency very carefully and call it F_1.

b. Tune upwards in frequency to the next response having a beat note of approximately the same intensity. Measure this frequency carefully and call it F_2. If only one strong response is found and it is not known whether the unknown is above, within, or below the fundamental range of the FM-5, switch ranges and repeat the procedure. When switching from low to high range use the procedure given in part 2 following.

c. If two responses have been found then it is obvious that the first response occurs at a frequency $NF_1 = X$ where N is some integer representing the harmonic being used and X is the unknown frequency. Similarly since the FM-5 is tuned upward in frequency to the next harmonic response, this response would occur at $(N-1)F_2 = X$ where N-1 indicated that the next lower harmonic of the FM-5 is being used when the F_2 was measured. We now have two equations in two unknowns. One unknown is the unknown frequency and the other the harmonic order. Solving these equations for n we obtain $n = \frac{F_2}{F_2 - F_1}$. Substituting the actual values of F_1 and F_2, we will obtain a value for n which will be very close to some integer. Experimental error will usually cause some deviation from the exact integer. Choosing the closest integer to the n obtained, and calling this value N, we may use the equation $X = NF_1$ to solve for the unknown frequency.

2. Frequencies known to be below the fundamental range generated by the instrument.

a. Starting at the low frequency end of the FM-5 dial, tune the search oscillator throughout its range, noting the loudest responses. Turn down the coupling control until the audio level decreases noticeably on the loud responses to avoid saturation in the detector system. Ignoring relatively weak responses, go back to the first strong one. Measure this frequency carefully and call it F_1.

b. Continue tuning upwards in frequency until the next response of approximately the same intensity is obtained. Measure this and

call it F_2. If only one strong response can be obtained and the unknown is known to be below the fundamental range of the instrument, then the response is the second harmonic and the frequency of the unknown would be F_1 divided by 2.

c. If a second response was obtained it is possible to solve for the unknown frequency using the two measurements. The first response must have been obtained at a frequency $F_1 = NX$ where N represents the harmonic of the source that was used in the measurement of F_1. Similarly the second response will occur at $F_2 = (N+1)X$ indicating that the next higher harmonic of the source was used. Solving these equations for n, we obtain $n = \frac{F_1}{F_2 - F_1}$.

Substituting the actual measurements into this equation, n will come out to be very close to some integral value. Choosing the closest integer to the n obtained, $X = \frac{F_1}{N}$.

3. Additional information on measurement of entirely unknown frequencies.

a. If an unknown frequency is not known to be above, within or below the fundamental range being used, at least three responses must be obtained. If this many proper responses cannot be obtained from the first range searched, they may be obtained by switching range, or by using the driver instrument without the FM-5.

b. When three or more responses have been obtained the unknown can be identified as being above or below the fundamental range of the instrument by substracting the readings obtained on successive responses. If the unknown frequency is below the range being used, the successive responses are adjacent harmonics of the unknown and are separated by the unknown frequency. Therefore, the difference between successive responses will be constant except for errors introduced in measurement. If the unknown frequency is above the range of the instrument, the difference between successive readings will not be constant.

c. When measuring frequencies below the fundamental range of the instrument the approximate unknown frequency can be obtained by subtracting the readings of two successive responses. This is not the most accurate means of determining the unknown frequency since it involves finding the small difference of two relatively large numbers, a situation which increases the percentage error introduced in measurement. To accurately measure the unknown, the harmonic order should be identified by the method shown in part 2 and the measured response divided by this integer. No loss of accuracy results from this procedure.

SECTION III - THEORY OF OPERATION

A. GENERAL

The FM-5 contains two regenerative frequency dividers (see Block Diagram, Figure III-1). Each divider divides its input frequency by exactly ten. It is possible for the instrument to divide its input frequency by either 10 or 100 depending on the position of the range switch. Both dividers are used in cascade to divide by 100.

A regenerative divider consists of a mixer and a multiplier. The input signal is fed to one grid of the mixer tube. If the divider is to divide by 10, a signal is fed to the other control grid of the mixer tube which has 9/10 the frequency of the input. The difference frequency, which is 1/10 of the input, is the useful output of the mixer and of the frequency divider. This frequency is also fed to a tuned harmonic multiplier which multiplies it by 9 to provide the second signal for the mixer. Resonant circuits are used in the mixer and multiplier to select the desired outputs. The tuned circuits effectively control the division ratio.

The first stage of the FM-5 is an oscillator when the function switch is in the BEAT position and an amplifier when it is in the LOCK position. In the BEAT position the oscillator drives the dividers so that the FM-5 generates a frequency which is controlled by the tuning dial and the range switch. This is used to set the FM-5 tuning dial to match an unknown frequency.

The output of one of the frequency dividers as selected by the range switch is fed through a crystal harmonic generator. The crystal is a non-linear impedance which distorts the output waveform to provide strong harmonics. This allows frequencies to be generated or measured considerably above the fundamental range of the instrument. For example, the 2-4 mc. output obtained with the range switch in the X. 1 position can easily be used to measure or generate frequencies in the range of 2-20 mc. by the use of harmonics. The output of the harmonic generator is available at the input-output jack. Signals fed into the input-output jack mix with signals from the harmonic generator at the grid of the detector tube. A grid leak detector followed by one stage of audio amplification is used. This system is used to detect the beat notes between the FM-5 and unknown signals and to adjust the output of the dividers to exactly match the unknown by the zero beat method. When the function switch is placed in the MOD position, the audio output stage is converted to an audio oscillator which modulates the RF output by feeding a signal to the harmonic generator crystal. This modulated output may be used to identify the FM-5 signal when calibrating a receiver.

B. DETAILED DESCRIPTION, (See Figure III-2)

1. Oscillator - Amplifier, VI

V-1, a 6BH6, is used as an oscillator when the function switch is in the BEAT position and as a tuned amplifier when the switch is in the LOCK and MOD positions. The plate circuit is tuned from 20 to 40 mc. by the front panel tuning control. A link is coupled to the plate inductor, L1, to provide feedback when the stage is used as an oscillator. An RF autotransformer, T1, is used to match the impedance of the driver to the amplifier input.

2. First Mixer, V-2

V2, a 6AS6, is used as the mixer section of the first divider. The 20-40 mc. signal from V-1 is fed to the second control grid of this tube. An 18-36 mc. signal from V4 is fed to the first control grid. The difference frequency, which is a 2-4 mc. signal is the useful output which is resistance coupled to the next stage. Resistance coupling is used to minimize the number of gang tuned circuits in the instrument. This stage uses grid leak bias. Grid leak bias gives high gain with zero signal, and improves the starting characteristics of the divider. Plate and screen resistors are large enough to avoid excessive power dissipation in the tube in the zero signal condition.

3. Amplifier, V-3.

V3, a 6AK5, is used in a 2-4 mc. tuned amplifier. This stage increases the output of the first divider and increases the available closed loop gain of the divider to make operation reliable. Grid leak bias is used to improve starting. A 3.3 K resistor, R 12, forms a Pi section RC filter with the output capacity of V2 and the input capacity of V3.

This is done to reduce the amount of 20-40 mc. signal transmitted through this stage and suppress a spurious mode of operation which results from the presence of 20-40 mc. input signal at the grid of V4. Two links are coupled to the plate circuit inductor of V3 to feed signal to the second divider and to YI, the harmonic generator diode, when the range switch is in the X. 1 position.

4. First Multiplier, V4.

This stage uses a 6BH6 to multiply its 2-4 mc. input by 9 and provide an output in the 18-36 mc. range. This output is fed back to V2 where it beats against the 20-40 mc. input signal. Grid leak bias is used in V4 with the grid resistor returned to the plate circuit of V3. This reduces the effective time constant of the coupling circuit and improves the stability of

operation. The screen resistor used with V4 is unusually large. This results in low screen voltage and a small "grid base", which improves the efficiency of harmonic generation. The plate circuit of V4 is tuned to 9 times the frequency of the 2-4 mc. signal.

5. Second Mixer, V5.

This is a 6AS6 mixer. Operation is similar to V2.

The 2-4 mc. output of V3 is fed to the second control grid. A 1.8 - 3.6 mc. signal from V6 is fed to the first control grid. The plate circuit is tuned to the 200-400 kc. difference frequency which is the useful output of the second divider. A link is coupled to the plate circuit inductor to feed signal to the harmonic generator when the range switch is in the X.01 position.

6. Second Multiplier, V6.

A 6BH6 is used for the multiplier section of the second divider. Operation is similar to the first divider. The output frequency is 9 times the 200-400 kc. signal. The 27K resistor, R19, in the grid circuit forms a low pass RC filter to suppress a spurious mode of operation. A combination of cathode bias and grid leak bias is used.

7. Harmonic Generator, YI.

A germanium diode is used to distort the output waveform. This diode has high forward conductance. The distorted output is coupled through C21 and C32 to the detector grid and RF level control. This RC coupling circuit tends to increase the percentage of harmonic signals at the output.

8. Detector, V7.

A 6BH6 is used in a pentode grid leak detector. This circuit is used because of its high gain. It is not a linear detector, but distortion is unimportant in this application. The plate circuit is impedance coupled to the audio output stage by means of a 600 henry coupling choke. This gives a high impedance to audio frequencies without the large voltage drop which would occur with resistance coupling. The resulting high plate voltage gives improved detector sensitivity.

9. Audio Amplifier, V8.

A 6BH6 is used in the audio output amplifier. The output transformer is designed to work with 600 ohm headphones. Phones with other impedances may be used with some loss of sensitivity. A feedback winding is

built into the output transformer so that the amplifier may be converted to an oscillator and used to modulate the RF output.

C36, a 40 mfd. capacitor, bypasses the B+ circuit to reduce coupling between the audio amplifier and the dividers.

SECTION IV - MAINTENANCE

1. ALIGNMENT

The FM-5 normally requires alignment when tubes are replaced or when the tuned circuits are altered by some phenomenon such as violent shock. Lack of alignment is indicated by low readings in the output meter and sometimes by loud noise in the headphones, caused by erratic operation of the dividers. The instrument must be removed from its case for alignment. To do this remove the power supply panel from the lower section of the carrying case and unplug the cable leading to the upper section. Remove the four screws in the sides of the case which hold the instrument in place and remove the instrument. Plug the power cable back into the instrument and turn on power. The adjustable slugs and trimmers used for alignment may be reached through holes in the left side of the instrument. Trimmers are reached through the bottom row of holes and slugs through the top row. See Figure IV-1. Always adjust slugs when tuned to the low frequency end of the dial and trimmers when tuned to the high frequency end. Specific instructions follow for alignment of the various sections.

A. Oscillator Section

The slug and trimmer for this section are available through the holes closest to the front panel. To adjust this section, set the function switch to the BEAT position and connect the FM-3 or AM-1 driver to the 20-40 mc. input-output jack. Plug headphones into the driver and adjust for exactly 20 mc. Tune the FM-5 dial to 40 and adjust the trimmer until zero beat is heard. Now tune the FM-5 dial to 20 and adjust the slug until zero beat is again heard. Repeat these steps until no further adjustment is necessary. It should not be necessary to readjust the driver since the second harmonic of the driver frequency can be used to adjust the oscillator to 40 mc.

B. First Divider

The adjustments for the first divider are available through the second and third vertical rows of holes back from the front panel. Turn the range switch to the X. 1 position. Leave the FM-5 in the BEAT position and adjust slugs with the FM-5 dial set to 20 and trimmers with the FM-5 dial set to 40. Adjust for a maximum indication on the front panel meter. With the 20-40 mc. input disconnected, turn the function switch to lock and back to beat several times at various frequencies throughout the range to be sure the divider starts properly. If trouble is encountered, adjust the slug if near the low end or the trimmer if near the high end to give reliable starting. Unless the adjustments required to align the instruments are very small, check to be sure

the divider is dividing by exactly 10. It is possible to adjust the instrument to divide by other ratios such as 9 or 11. To check this connect the driver instrument to the 200 kc. - 20 mc. input-output jack and use the driver to measure the frequency output with the FM-5 in the BEAT position. With the FM-5 dial set to 20, a strong response should be heard in the driver every 2 megacycles. With the FM-5 dial set to 40, a strong response should be heard every 4 megacycles.

C. Second Divider

The adjustments for the second divider are reached through the rear two vertical rows of holes. Turn the range switch to the X. 01 position and follow the same procedure outlined in Step B above. Division ratio may be checked by the same method. With the FM-5 in the BEAT position and the dial set to 20 a strong response should be heard in the driver every 200 kc. With the dial set to 40 a strong response should be heard every 400 kc.

D. Dial Alignment

If the position of the dial on the capacitor shaft has been disturbed for any reason, the following alignment procedure should be followed:

1. Loosen the set screws in the dial hub.

2. Push the capacitor to the stop at the fully closed position.

3. Turn the dial so that the short mark which is off-scale near 20 lines up with the hairline. To eliminate parallax error, hold the head so that the reflection of the eye in the window is centered on the hairline.

4. Tighten the set screws without disturbing the position of the dial on the shaft. Check this.

5. Track the oscillator and dividers to the dial as described in parts IV A, B, and C.

E. Correction of Severe Misalignment

If tuned circuit components are replaced or several circuits are badly detuned, difficulty may be encountered in aligning the dividers because a divider will not run unless both tuned circuits in the system are approximately aligned. This may be accomplished by the use of a "Grid Dip Meter" or other resonance indicator. Proceed as follows:

1. Check dial mechanical alignment as described in part "D".

2. Track the oscillator to the dial as described in part "A".

3. If the instrument works properly in the X. 1 position, adjust only the second divider. Otherwise, adjust the first divider until proper operation is obtained and then adjust the second divider if necessary. Tune the various circuits according to the following table:

	Set Dial to 20 MC. Adjust Slugs For Resonance At:	Set Dial to 40 MC. Adjust Trimmers For Resonance At:
First Divider:		
Amplifier	2.0 mc.	4.0 mc.
Multiplier	18.0 mc.	36.0 mc.
Second Divider:		
Mixer	200 kc.	400 kc.
Multiplier	1.8 mc.	3.6 mc.

The instrument need not be energized while making these adjustments since indications are obtained from the external resonance indicator. Alternate between 20 mc. and 40 mc. adjustments until no further adjustment is necessary.

4. Energize the instrument in the BEAT position. Set the dial to 20 mc. Rock the two slugs of the divider being adjusted until the front panel meter indicates the divider is working.

5. Tune slowly upwards in frequency. Adjust trimmers to keep the divider at maximum output. Stop and return to step 4 when appreciable adjustment of the trimmers is required.

6. When the divider works over the entire frequency range, proceed according to parts B and C.

2. TROUBLE SHOOTING

The front panel output meter may be used to advantage in locating trouble in the FM-5. With the function switch in the BEAT position trouble in the second divider would be indicated by the meter showing normal output with the range switch in the X. 1 position but no output with the range switch in the .01 position. When switching to the .01 position it may be necessary to wait about 30 seconds for the second divider tubes to warm up since the heaters of these tubes are connected through the range switch. If the output meter shows no reading on either range, trouble in the power supply, oscillator, or first divider is indicated. Operation of the oscillator may be checked by

connecting the driver to the 20 - 40 mc. input jack. A loud signal should be heard from the driver when it is tuned to the frequency indicated on the FM-5 dial. If the oscillator is working the trouble would be in the first divider, otherwise it may be in the oscillator or power supply. Normal voltages are indicated on the circuit diagram to simplify trouble shooting the individual stages with a VTVM. Alignment should be checked when any tube or component associated with a tuned circuit is replaced.

3. BATTERY EXHAUSTION

A battery operated FM-5 should operate satisfactorily until the batteries drop to about 75% of their rated voltage under load. As the batteries become weak, sensitivity will decrease and the front panel meter will show decreasing output. Eventually, the dividers will refuse to start or will operate erratically, causing loud crackling noises in the headphones. If any of these symptoms appear, remove the battery compartment cover and check battery voltages with the instrument operating. Set the function switch to BEAT and the range switch to X. 01. Replace the 6 volt filament batteries if they produce less than 4. 7 volts. Replace any 45 volt B+ batteries which produce less than 35 volts. The string of three batteries should produce at least 105 volts. Replace doubtful batteries if difficulty is encountered in operation.

4. INSTALLATION OF BATTERIES.

A. Remove the battery compartment cover.

B. Loosen the screw at the left hand side of the battery hold down bar.

C. Lift the battery holddown bar toward the top of the instrument as far as it will go. The other end of the holddown bar may now be pulled from its position.

D. Remove and replace batteries. See Fig. IV-2, battery location diagram.

E. Replace the right hand end of the battery holddown bar in its retainer. Slide the holddown bar back to its normal position under the screw at the left hand side and tighten the screw.

F. Replace the battery compartment cover.

5. CONVERSION OF FM-5/PS-3 OR FM-5R FOR 230 VOLT OPERATION

Reconnect jumpers on the power supply terminal board according to Fig. IV-3.

SECTION V - PARTS LIST

Symbol	Description	Manufacturer & Designation
R1	Resistor: fixed, composition, 27 K ohm, ±10%, 1/2 W.	Allen-Bradley
R2	Resistor: fixed, composition, 27 ohm, ±10%, 1/2 W.	" "
R3	Resistor, fixed, composition, 150 ohm, ±10%, 1/2 W.	" "
R4	Resistor: fixed, composition, 1 K ohm, ±10%, 1/2 W.	" "
R5	Resistor: fixed, composition, 100 K ohm, ±10%, 1/2 W.	" "
R6	Resistor: fixed, composition, 47 K ohm, ±10%, 1/2 W.	" "
R7	Resistor: fixed, composition, 4.7 K ohm, ±10%, 1/2 W.	" "
R8	Resistor: fixed, composition, 6.8 K ohm, ±10%, 1/2 W.	" "
R9	Resistor: fixed, composition, 15 K ohm, ±10%, 1/2 W.	" "
R10	Resistor: fixed, composition 100 ohm, ±10%, 1/2 W.	" "
R11	Resistor: fixed, composition, 470 K ohm, ±10%, 1/2 W.	" "
R12	Resistor: fixed, composition, 3.3 K ohm, ±10%, 1/2 W.	" "
R13	Resistor: fixed, composition, 150 K ohm, ±10%, 1/2 W.	" "
R14	Resistor: fixed, composition, 1 K ohm, ±10%, 1/2 W.	" "

Symbol	Description	Manufacturer & Designation
R15	Resistor: fixed, composition, 47 K ohm, ±10%, 1/2 W.	Allen - Bradley
R16	Resistor: fixed, composition, 1 megohm, ±10%, 1/2 W.	" "
R17	Resistor: fixed, composition, 2.7 K ohm, ±10%, 1/2 W.	" "
R18	Resistor: fixed, composition, 330 K ohm, ±10%, 1/2 W.	" "
R19	Resistor: fixed, composition, 27 K ohm, ±10%, 1/2 W.	" "
R20	Resistor: fixed, composition, 1 K ohm, ±10%, 1/2 W.	" "
R21	Resistor: fixed, composition, 15 K ohm, ±10%, 1/2 W.	" "
R22	Resistor: fixed, composition, 100 K ohm, ±10%, 1/2 W.	" "
R23	Resistor: fixed, composition, 680 K ohm, ±10%, 1/2 W.	" "
R24	Resistor: fixed, composition, 1 K ohm, ±10%, 1/2 W.	" "
R25	Resistor: fixed, composition, 330 K ohm, ±10%, 1/2 W.	" "
R26	Potentiometer: composition, 1,000 ohm, linear taper, 2 Watt.	Ohmite Type AB CU 1021
R27	Resistor: fixed, composition, 1 megohm, ±10%, 1/2 Watt	Allen - Bradley
R28	Resistor: Fixed, wirewound, 0.62 ohm, ±5%, 1/2 W.	IRC Type BW 1/2
R29	Resistor: Fixed, wirewound, 4.7 ohm, ±10%, 1/2 W.	IRC Type BW 1/2

Symbol	Description	Manufacturing & Designation
R30	Resistor: fixed, composition, 100 K ohm, ±10%, 1/2 W.	Allen - Bradley
R31	Resistor: fixed, composition, 1 megohm, ±10%, 1/2 W.	" "
R32	Resistor: fixed, composition, 330 ohm, ±10%, 1/2 W.	" "
R33	Resistor: fixed, composition, 180 K ohm, ±10%, 1/2 W.	" "
R34	Resistor: fixed, composition, 3.9 megohm, ±10%, 1/2 W.	" "
R35	Resistor: fixed, composition, 470 ohm, ±10%, 1/2 W.	" "
R36	Resistor: fixed, composition, 8.2 K ohm, ±10%, 1/2 W.	"
R37	Resistor: fixed, composition, 100 ohm, ±10%, 1/2 W.	" "

Symbol	Description	Manufacturer & Designation
C1	Capacitor: variable, air, 5 Gang, GPI Part No. 4399	Radio Condenser Corp.
C2	Capacitor: fixed, ceramic, 56 uuf., ±20%, 500 VDCW GP1 K	Erie GP1 K 56 ±11.2
C3	Capacitor: fixed, ceramic, .01 uf., 500 VDCW	Erie Type 811
C4	Capacitor: fixed, ceramic, .01 uf., 500 VDCW	Erie Type 811
C5	Capacitor: fixed, ceramic, .01 uf., 500 VDCW	Erie Type 811
C6	Capacitor: variable, ceramic, 3-12 uuf., NPO	Erie TS2A-3
C7	Capacitor: fixed, ceramic, 27 uuf., ±20%, 500 VDCW, GP1 K	Erie GP1 K 27 ±5.4
C8	Capacitor: fixed, ceramic, .01 uf., 500 VDCW	Erie Type 811
C9	Capacitor: fixed, ceramic, .01 uf., 500 VDCW	Erie Type 811
C10	Capacitor: fixed, ceramic, 27 uuf., ±20%, 500 VDCW GP1 K	Erie GP1 K 27 ±5.4

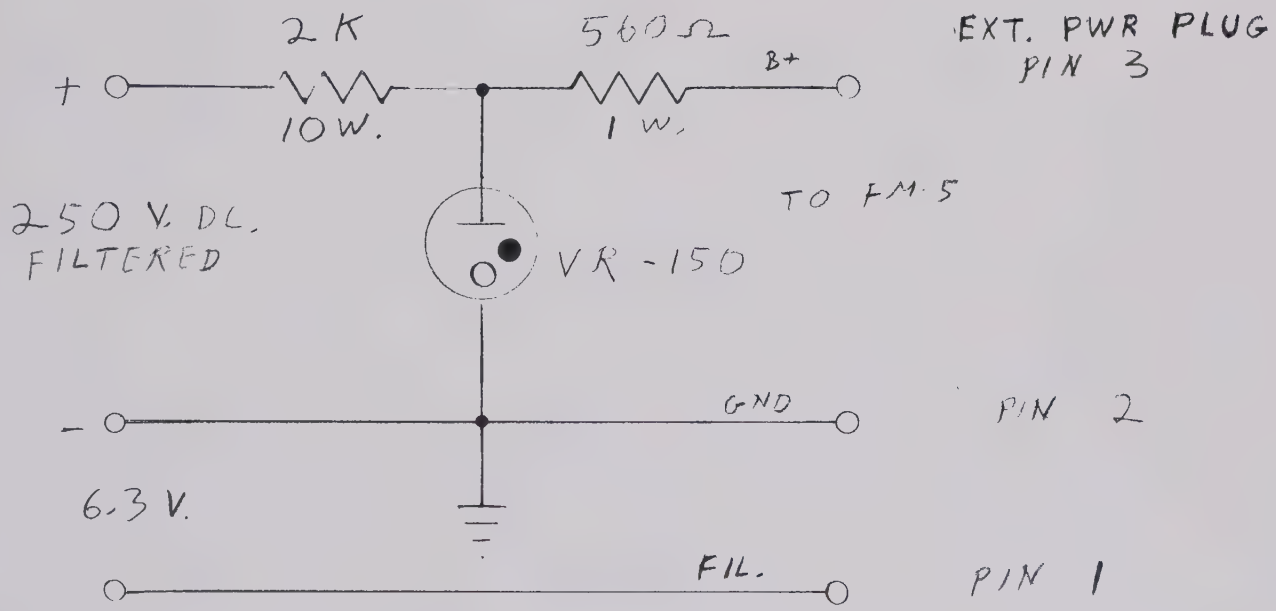
Symbol	Description	Manufacturer & Designation
C11	Capacitor: fixed, ceramic .01 uf, 500 VDCW	Erie Type 811
C12	Capacitor: fixed, ceramic .01 uf, 500 VDCW	" "
C13	Capacitor: variable, ceramic 3-12 uuf, NPO	Erie TS2A-3
C14	Capacitor: fixed, ceramic, 27 uuf, ±20%, 500 VDCW, GP1K	Erie GP1K 27 ±5.4
C15	Capacitor: fixed, ceramic, .01 uf., 500 VDCW	Erie Type 811
C16	Capacitor: fixed, ceramic, .01 uf., 500 VDCW	" "
C17	Capacitor: variable, ceramic, 3-12 uuf, NPO	Erie TS2A-3
C18	Capacitor: fixed, ceramic 27 uuf, ±20%, 500 VDCW,GP1K	Erie GP1K 27 ±5.4
C20	Capacitor: fixed, paper, .05 uf., ±20%, 200 VDCW	Aerovox Type P82
C21	Capacitor: fixed, ceramic .01 uf., 500 VDCW	Erie Type 811
C22	Capacitor: Variable, ceramic, 7-45 uuf, N 500.	Erie TS2A-7
C23	Capacitor: fixed, ceramic, 22 uuf., ±10%, 500 VDCW, NPOK	Erie NPOK 22 ±22
C24	Capacitor: fixed, ceramic, 10 uuf, ±10%, NPOK	Erie NPOK 10 ±1.0
C25	Capacitor: fixed, paper, .05 uf., ±20%, 200 VDCW	Aerovox Type P82
C26	Capacitor: fixed, ceramic, .01 uf., 500 VDCW	Erie Type 811

Symbol	Description	Manufacturer & Designation
C27	Capacitor: variable, ceramic, 7-45 uuf., N500	Erie TS2A-7
C28	Capacitor: fixed, ceramic, 22 uuf., ±10%, 500 VDCW NPOK	Erie NPOK 22 ±2.2
C29	Capacitor: fixed, silvered mica, 110 uuf., ±5%, 500 VDCW CM-15 Case.	El - Menco
C30	Capacitor: fixed, paper, .5 uf, ±20%, 200 VDCW	Aerovox Type P82
C31	Capacitor: fixed, silvered mica, 110 uuf., ±5%, 500 VDCW, CM-15 Case	El-Menco
C32	Capacitor: fixed, silvered mica, 110 uuf., ±5%, 500 VDCW, CM-15 Case	El-Menco
C33	Capacitor: fixed, paper, .05 uf., ±20%, 200 VDCW	Goodall Type M-503
C34	Capacitor: fixed, paper, .003 uf., +40% -20%, 600 VDCW	Goodall Type M-503
C35	Capacitor: fixed, paper, .05 uf., ±20%, 200 VDCW	Goodall Type M-503
C36	Capacitor: fixed, electrolytic 40 uf., 350 VDCW	Cornell Dubilier BR 4035
C37	Capacitor: fixed, electrolytic, 10 uf., 25 VDCW	Cornell Dubilier BBR 10-25
C38	Capacitor: fixed, ceramic, 1000 uuf, ±20%, 500 VDCW GP2L.	Erie GP2L1000 ±200
C39	Capacitor: fixed, silvered mica, 55 uuf., ±5%, 500 VDCW, CM-15 Case.	El Menco
C40	Capacitor: fixed, ceramic, .01 uf., 500 VDCW.	Erie Type 811

Symbol	Description	Manufacturer & Designation
C41	Capacitor: fixed, ceramic, 15 uuf., ±10%, 500 VDCW NPOK	Erie NPOK 15 ± 1.5

Symbol	Description	Manufacturer & Designation
V1	Tube: 6BH6	
V2	Tube: 6AS6	
V3	Tube: 6AK5	
V4	Tube: 6BH6	
V5	Tube: 6AS6	
V6	Tube: 6BH6	
V7	Tube: 6BH6	
V8	Tube: 6BH6	
I1	Lamp: Miniature 6.3 V.	Tung-Sol TS-51
L1	Inductor: Adjustable .44 uH.	GPI No. LS-14
L2	Inductor: Adjustable 43.5 uH.	GPI No. LS-15
L3	Inductor: Adjustable .54 uH.	GPI No. LS-16
L4	Inductor: Adjustable 1650 uH.	GPI No. LS-17
L5	Inductor: Adjustable 20.5 uH.	Miller No. 4407
L6	Inductor: RF Choke, 10 uH.	Standard Coil # XM401
L7	Inductor: Audio Coupling, 600 H. at 1 MA.	Triad # 14881
T1	Autotransformer: RF, Powdered Iron Core.	GPI No. LS-18
T2	Transformer: Audio output.	Triad No. 2426
S1	Switch: Rotary Wafer, 8 Pole, 4 Position.	Oak No. 52898-F4

Symbol	Description	Manufacturer & Designation
S2	Switch: Rotary Wafer, 2 Pole, 2 Position.	Centralab PA2003
M1	Meter: 0-1 MA.	International Instruments A-SP-361-2C
Y1	Diode: Germanium.	Transitron Type T6
P1	Plug: Power 6 Pin Male	Jones #P306 AB
J1	Jack: Phone	Switchcraft No. 11



FM-5

SUGGESTED REGULATOR CKT.

FIG. I-1

SCALE:	APPROVED BY	DRAWN BY
DATE:		REVISED
JOB		DRAWING NUMBER

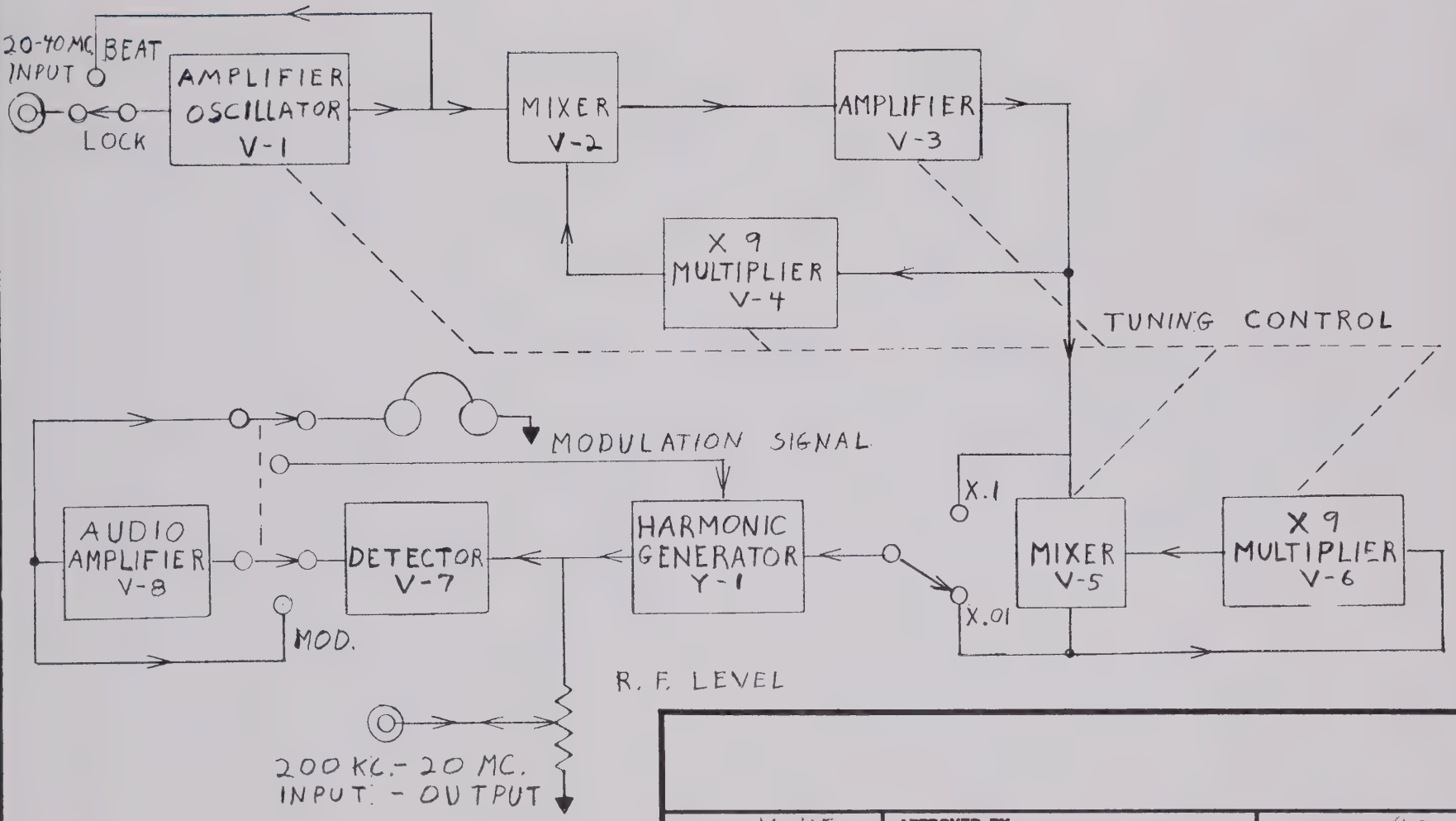


FIG. III-1

SCALE: NONE	APPROVED BY	DRAWN BY KDS
DATE: 12-10-54		REVISED

FM-5 BLOCK DIAGRAM

JOB	DRAWING NUMBER
439.9	

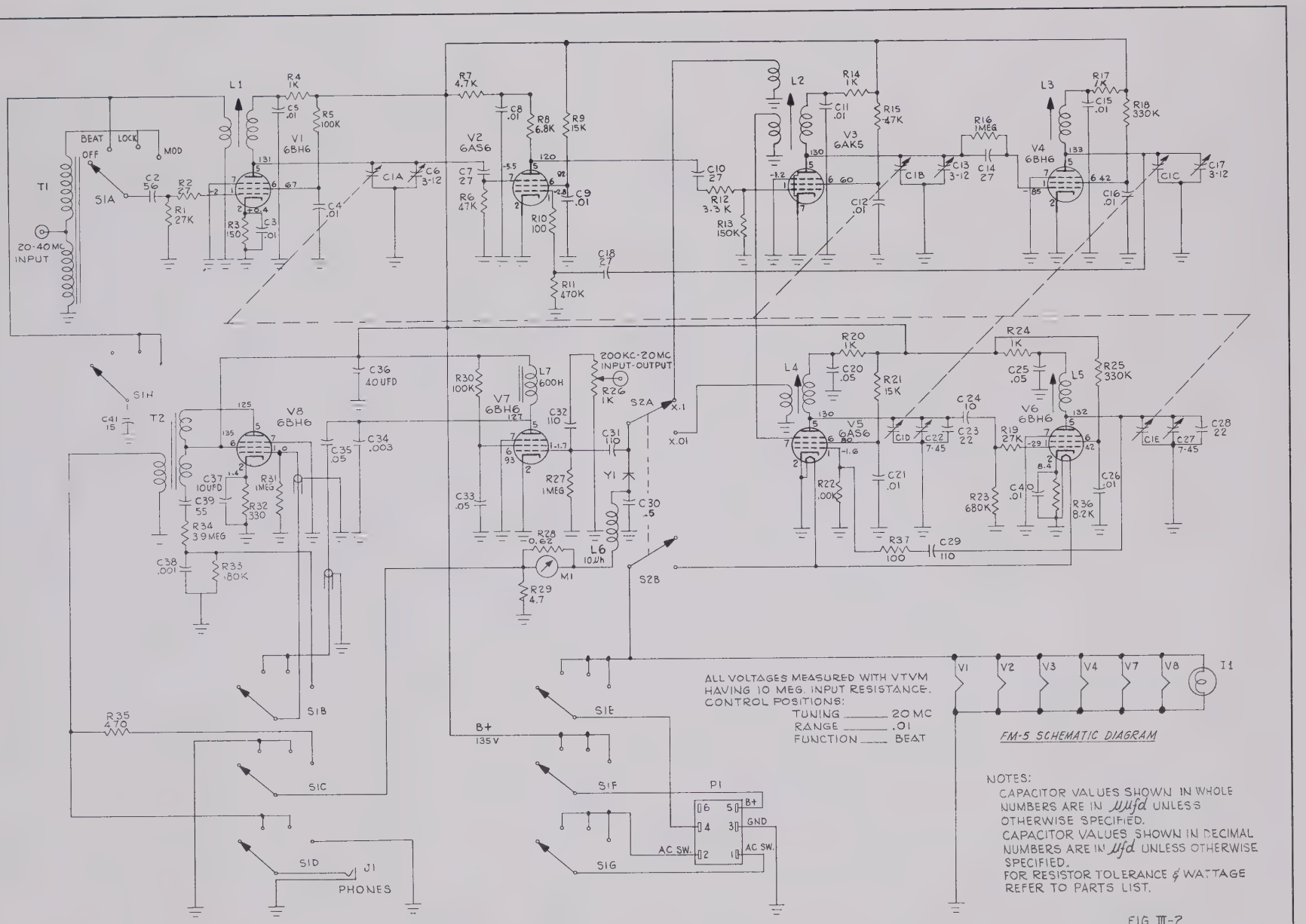

BEAT
LOCK
MOD
OFF
S1A
T1
20-40MC INPUT
L1
V1 6BH6
V2 6AS6
V3 6AK5
L2
L3
V4 6BH6
V5 6AS6
V6 6BH6
L4
L5
L6 10μh
L7 600H
V7 6BH6
V8 6BH6
T2
S1H
S1B
S1C
S1D
J1
PHONES
S1E
S1F
S1G
P1
B+
GND
AC SW.
AC SW.
B+ 135V
200KC-20MC INPUT-OUTPUT
S2A
S2B
X.1
X.01
M1
Y1
V1
V2
V3
V4
V7
V8
I1
ALL VOLTAGES MEASURED WITH VTVM HAVING 10 MEG. INPUT RESISTANCE.
CONTROL POSITIONS:
TUNING ____ 20 MC
RANGE ____ .01
FUNCTION ____ BEAT
FM-5 SCHEMATIC DIAGRAM
NOTES:
CAPACITOR VALUES SHOWN IN WHOLE NUMBERS ARE IN μμfd UNLESS OTHERWISE SPECIFIED.
CAPACITOR VALUES SHOWN IN DECIMAL NUMBERS ARE IN μfd UNLESS OTHERWISE SPECIFIED.
FOR RESISTOR TOLERANCE & WATTAGE REFER TO PARTS LIST.

FIG. III-2

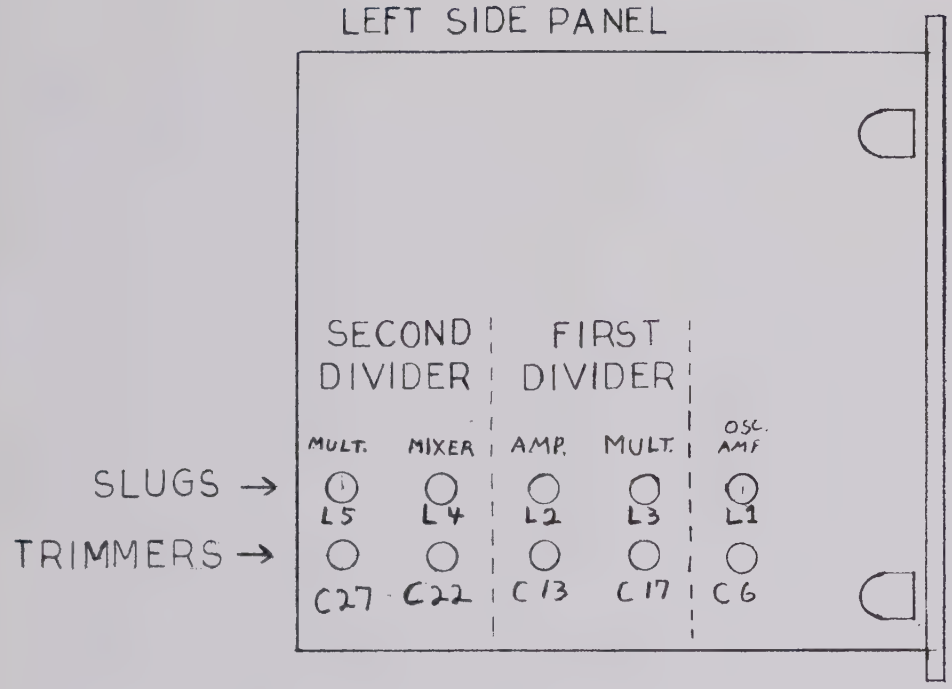


FIG. IV-1

SCALE:	APPROVED BY	DRAWN BY RJL
DATE: 12-28-54		REVISED

FM-5 TRIMMER & SLUG LOCATIONS

JOB	DRAWING NUMBER
439.9	

BATTERY COMPARTMENT - FRONT VIEW.

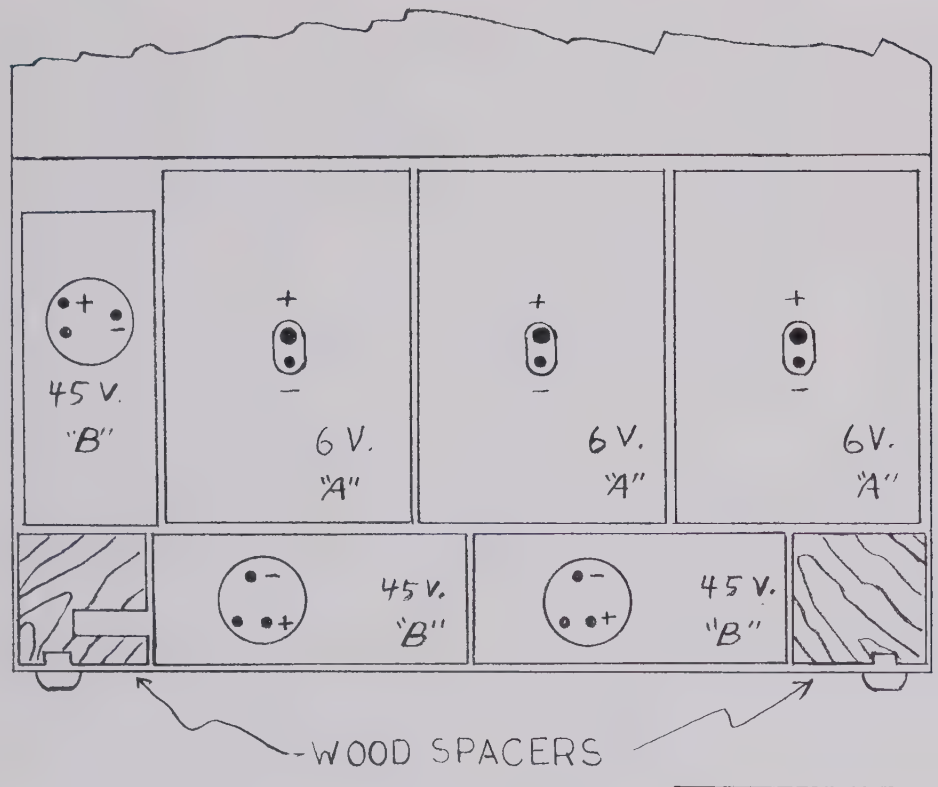


FIG. IV-2

SCALE:	APPROVED BY	DRAWN BY K.Q.K.
DATE: 12-28-34		REVISED
FM-5 BATTERY LOCATIONS		
JOB 431.9		DRAWING NUMBER

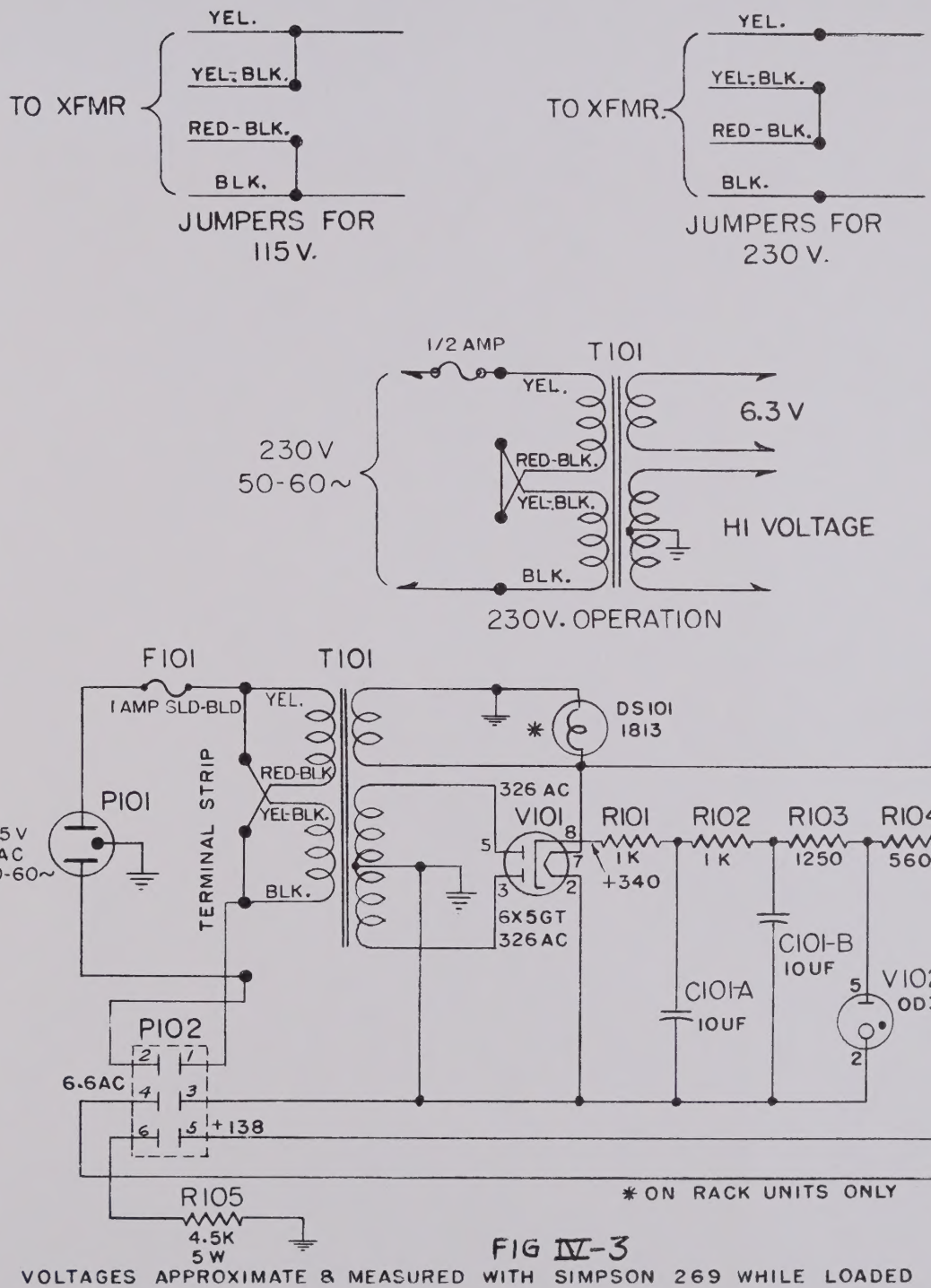


FIG IV-3

VOLTAGES APPROXIMATE & MEASURED WITH SIMPSON 269 WHILE LOADED